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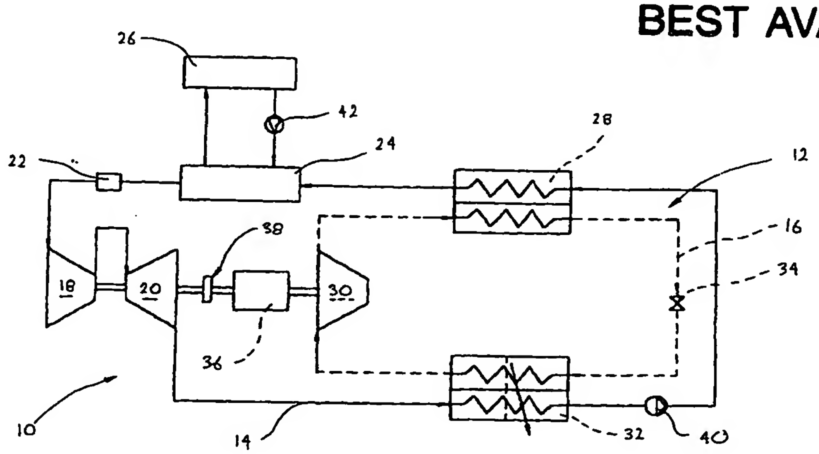

(57) Abstract: The present invention relates generally to a thermo-volumetric motor (10) together with a vapour compression refrigeration system (12) each including a respective continuous fluid path (14) and a continuous vapour-compression refrigeration cycle (16). The continuous fluid path or thermo-volumetric cycle (14) includes a pair of turbines (18) and (20) connected to one another via a common shaft. The thermo-volumetric cycle (14) also includes a mixing chamber (22) and a heat exchanger (24) located upstream of the turbines (18) and (20). The vapour-compression refrigeration cycle of this example is a standard air conditioning refrigeration cycle. The cycle (16) includes a condenser (28) a compressor (30) and evaporator (32) and an expansion valve (34) connected together in a conventional manner. The thermo-volumetric cycle (14) is in heat conductive communication with both the condenser (28) and the evaporator (32). The turbine or expeller (20) is mechanically coupled to an electrical motor (36) via a belt drive (38) wherein rotation of the turbines (18) and (20) effects rotation of the motor (30) which drives the compressor (30).

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A SEMI SELF SUSTAINING THERMO-VOLUMETRIC MOTOR

FIELD OF THE INVENTION

The present invention relates generally to a thermo-volumetric motor and relates particularly, though not exclusively, to a thermo-volumetric motor utilising a vapour-compression refrigeration cycle or a vapour-absorption refrigeration cycle for improved heating/cooling and/or power production.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a thermo-volumetric motor comprising a continuous fluid path adapted to carry a working fluid, said path including one or more turbines or a hydraulic motor at least one of which is operatively coupled to a compressor of a vapour-compression refrigeration system, the fluid path adapted to be in heat conductive communication with at least a condenser of the vapour-compression refrigeration system whereby in operation the working fluid recovers latent heat from the condenser to effect expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the vapour-compression refrigeration system, said fluid thereafter condensing and recirculating to recover latent heat from the condenser.

Preferably the continuous fluid path is also adapted, between said turbines or the hydraulic motor and the condenser, to be in heat conductive communication with an evaporator of the vapour-compression refrigeration system whereby in use the latent heat of vaporisation of a refrigerant gas flowing through the evaporator effects

cooling of the working fluid. Alternatively the fluid path is not in heat conductive communication with the condenser and the fluid path additionally comprises a working fluid condenser positioned downstream of said turbines or the hydraulic motor. According to another variant the fluid path may include a turbine compressor or a boundary layer pump coupled to and thus driven by the turbines or the hydraulic motor, the turbine compressor or the boundary layer pump located downstream of said turbines or the hydraulic motor.

Typically the continuous fluid path further comprises a heat exchanger disposed between the condenser of the vapour-compression refrigeration system and said one or more turbines or the hydraulic motor, the heat exchanger adapted to be in heat conductive communication with an external heat source which thus transfers heat to the working fluid in the continuous fluid path via the heat exchanger. Generally the external heat source can be a combusted fossil or other fuel or waste heat from a combustion engine such as a diesel exhaust, a water radiator jacket, solar, geothermal, wood kiln or other sources of waste heat. Alternatively the fluid path does not include the heat exchanger and thus is not in heat communication with an external heat source but rather an electrical motor coupled to the compressor and said turbines or the hydraulic motor is driven by an external electrical power supply.

Typically the continuous fluid path includes multiple turbines coupled to one another, one of said multiple turbines being operatively coupled via a mechanical drive such as a belt drive to the compressor or an electric

motor connected to the compressor. Generally the continuous fluid path also includes one or more mixing chambers located upstream of the multiple turbines, said chambers each being designed to receive and mix a gas and a liquid component of the working fluid so as to produce a wet gaseous working fluid. In this instance the multiple turbines are boundary-layer turbines which operate effectively with the wet gaseous working fluid.

Typically said one or more turbines or the hydraulic motor are mechanically coupled to a power generator designed for electrical or motive power generation in static or mobile applications from small to large sizes such as that required in power houses, vehicles or boats.

Generally the continuous fluid path further includes a pump being designed to recirculate the working fluid around said path.

According to another aspect of the present invention there is provided an air conditioning system and a thermo-volumetric motor combination comprising:

a continuous vapour-compression refrigeration cycle adapted to carry a refrigerant or working fluid, said cycle including at least a compressor located upstream of a condenser which is positioned upstream of an evaporator; and

a continuous fluid path adapted to carry an other working fluid, said path including one or more turbines or a hydraulic motor being coupled to the compressor, the fluid path being in heat conductive communication with at least the condenser whereby in operation the other working fluid recovers latent heat from the condenser to effect

expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the air conditioning system, said other working fluid thereafter condensing and recirculating to recover latent heat from the condenser.

According to a further aspect of the present invention there is provided a method of generating motive power, said method comprising the steps of:

providing a thermo-volumetric motor including a continuous fluid path adapted to carry a working fluid, said path including one or more turbines or a hydraulic motor;

coupling one of said turbines or the hydraulic motor to a compressor of a vapour-compression refrigeration system; and

coupling the continuous fluid path to the vapour-compression refrigeration system wherein at least a condenser of the vapour-compression refrigeration system is in heat conductive communication with said path whereby in operation the working fluid recovers latent heat from the condenser to effect expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the vapour-compression refrigeration system, said fluid thereafter condensing and recirculating to recover latent heat from the condenser.

According to yet another aspect of the present invention there is provided a thermo-volumetric motor comprising a continuous fluid path adapted to carry a working fluid, said path being formed of a single stream and dual streams, the single stream including one or more turbines

or a hydraulic motor at least one of which is operatively coupled to a compressor of a vapour-compression refrigeration system or a boundary layer pump, and a vapour/liquid separator located downstream of said turbines or the hydraulic motor, the separator providing vapour and liquid to each of the respective dual streams, one of the dual streams including the compressor or the boundary layer pump which is designed to pressurise the vapour, the dual streams together being connected to and in heat conductive communication with a condenser such that the latent heat of the pressurised vapour is exchanged with the liquid in the other of the dual streams, said dual streams thereafter combining for mixing of the vapour and liquid which drives said one or more turbines or the hydraulic motor which thus drives the compressor or the boundary layer pump of the vapour-compression refrigeration system.

According to yet a further aspect of the present invention there is provided a vapour-absorption refrigeration system and a thermo-volumetric motor combination comprising a continuous vapour-absorption cycle being adapted to carry a refrigerant/working fluid and water mixture, said cycle including a condensor located upstream of a heat generator which is upstream of one or more turbines or a hydraulic motor operatively coupled to a generator whereby in operation the heat generator effects partial vaporisation of the refrigerant/working fluid and water mixture wherein a refrigerant gas fraction is expanded through said turbines or the hydraulic motor which drives the generator, and an unevaporated fraction of said mixture is diverted to the condensor and combined with the expanded

refrigerant gas fraction in the condensor and thereafter recirculated to the heat generator.

According to still another aspect of the present invention there is provided a method of generating motive power, said method comprising the steps of:

providing a continuous vapour-absorption cycle being adapted to carry a refrigerant/working fluid and water mixture, said cycle including a condensor located upstream of a heat generator which is upstream of one or more turbines or a hydraulic motor operatively coupled to a generator;

evaporating at least part of the refrigerant/working fluid mixture in the heat generator;

expanding a refrigerant gas fraction of said mixture through the turbines or the hydraulic motor which thus drives the generator; and

diverting an unevaporated fraction of said mixture from the heat generator to the condensor where it is combined with the expanded refrigerant gas fraction in the condensor and thereafter recirculated to the heat generator.

According to still a further aspect of the present invention there is provided a thermo-volumetric motor comprising:

one or multiple power cycles each having a continuous stream being adapted to carry a compressible fluid and a common continuous stream being adapted to carry an incompressible fluid;

a hydraulic cylinder dedicated to each of the power cycles wherein the compressible fluid and the

incompressible fluid flows to opposite sides of the respective cylinder;

a hydraulic motor included in the common continuous stream, said motor being operatively coupled to a generator; and

a heat exchanger dedicated to each of the continuous streams, said heat exchanger being operatively coupled to a waste heat source whereby in operation the compressible fluid is heated via the waste heat source in the heat exchanger and expanded through the respective hydraulic cylinder which recirculates the incompressible fluid through the common continuous stream and the hydraulic motor which thus drives the generator.

Alternatively or additionally the multiple power cycles are in heat conductive communication with each other.

According to an additional aspect of the present invention there is provided a method of generating motive power, said method comprising the steps of:

providing a thermo-volumetric motor including one or more power cycles each having a continuous stream being adapted to carry a compressible fluid and a common continuous stream being adapted to carry an incompressible fluid, a hydraulic cylinder dedicated to each of the power cycles and a hydraulic motor included in the common continuous stream;

heating the compressible fluid in each of the continuous streams and expanding said fluid through the respective hydraulic cylinder; and

recirculating the incompressible fluid through the common continuous stream via the hydraulic cylinders

thereby driving the hydraulic motor and a generator to which it is operatively coupled.

Generally the working fluid includes but is not limited to hydrochlorofluorocarbons (HCFCs) R123, R22, hydrofluorocarbons (HFCs) R134a, ammonia, hydrocarbons (HCs) n-butane, isobutane, isopentane or propane gas. Alternatively, the working fluid includes but is not limited to steam for high temperature applications.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to achieve a better understanding of the nature of the present invention several embodiments of a thermo-volumetric motor and method of generating motive power together with other aspects of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic of a thermo-volumetric motor together with a vapour-compression refrigeration system;

Figure 2 is a schematic of another thermo-volumetric motor together with a vapour-compression refrigeration system;

Figure 3 is a schematic of a further thermo-volumetric motor in conjunction with a vapour-compression refrigeration system;

Figure 4 is a schematic of yet another thermo-volumetric motor in conjunction with a vapour-compression refrigeration system;

Figure 5 is a schematic of a thermo-volumetric motor together with a compressor of a vapour-compression refrigeration system;

Figure 6 is a schematic of another thermo-volumetric motor together with a vapour-compression refrigeration system;

Figure 7 is a schematic of yet another thermo-volumetric motor in conjunction with a vapour-compression refrigeration system;

Figure 8 is a schematic of a further thermo-volumetric motor in conjunction with a vapour-absorption refrigeration system; and

Figure 9 is a schematic of an apparatus for producing motive power utilising waste heat from in this example a diesel engine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in Figures 1 to 4 there are various embodiments of a thermo-volumetric motor 10 together with a vapour-compression refrigeration system 12. For ease of reference and to avoid repetition those components and assemblies of Figures 2 to 4 which generally correspond to components and assemblies of Figure 1 have been designated with the Figure numeral prefixing like components and assemblies. For example, the thermo-volumetric motor of Figures 2, 3, and 4 have been designated as 210, 310, and 410, respectively. Furthermore, the embodiments of a thermo-volumetric motor shown in Figures 7 and 8 are in essence similar to that of Figures 2 and 4, respectively, except for the turbines having been replaced with a hydraulic motor.

The thermo-volumetric motor 10 and vapour-compression refrigeration system 12 of Figure 1 include a continuous fluid path 14 and a continuous vapour-compression refrigeration cycle 16, respectively. In this example

both the fluid path 14 and the vapour-compression refrigeration cycle 16 are adapted to carry a working fluid in the form of a refrigerant gas such as R123, R22, R134a, ammonia, n-butane, isobutane, isopentane or propane gas.

The continuous fluid path or thermo-volumetric cycle 14 of this embodiment includes a pair of turbines 18 and 20 connected to one another via a common shaft. The turbines 18 and 20 are of a boundary-layer drag type.

The thermo-volumetric cycle 14 also includes a mixing chamber 22 and a heat exchanger 24 located upstream of the turbines 18 and 20. The mixing chamber 22 is important in mixing liquid and vapour fractions or components of the working fluid, in this example a refrigerant gas, so as to produce a wet gaseous working fluid which is required for effective operation of the turbines 18 and 20. The heat exchanger 24 may be of a shell and tube construction preferably with the refrigerant gas flowing through the shell. The heat exchanger 24 is in heat conductive communication with a heat source 26 which can be a combusted fossil or other fuel or waste heat from a combustion engine such as a diesel exhaust, a water radiator jacket, solar, geothermal, wood kiln, or other sources of waste heat.

The vapour-compression refrigeration cycle 16 of this example is a standard air conditioning refrigeration cycle. The cycle 16 includes a condenser 28, a compressor 30, an evaporator 32, and an expansion valve 34 connected together in a conventional manner. The condenser 28 is typically a plate exchanger whereas the evaporator 32 is

generally a tube-in-tube exchanger. The compressor 30 may be driven by an electrical motor 36.

The thermo-volumetric cycle 14 of Figure 1 is in heat conductive communication with both the condenser 28 and the evaporator 32. The turbine or expeller 20 is mechanically coupled to the electrical motor 36 via a belt drive 38 or other suitable couplings or connections. Thus, rotation of the turbines 18 and 20 effects rotation of the motor 36 which drives the compressor 30. In this example, a portion of the thermo-volumetric cycle defines a tube of the evaporator 32 and further downstream a flow passage of the plate-type condenser 28.

In a standard vapour-compression refrigeration cycle such as that described the coefficient of performance (COP) is defined as:

COP = Heating or cooling load (W) / compressor power (W).

Depending on operational parameters it is generally recognised that the COP of the standard air conditioning refrigeration can be from three to five. That is, a COP of three means that the system efficiency is 300% whereby the system can produce a heating or cooling output three times that of the power input. This will hereinafter be generally referred to as the COP effect.

A significant feature of the present invention relates to utilisation of the COP effect in the thermo-volumetric motor such as 10. It will be appreciated that by coupling the thermo-volumetric motor 10 to the standard vapour-compression refrigeration cycle 12 that the overall system performance is enhanced by maximising waste heat recovery

from the refrigeration cycle 12 utilising the COP effect. In particular, the COP effect is to return heat to the thermo-volumetric motor 10 which thereby at least reduces its need for external heat. Accordingly the thermo-volumetric motor 10 drives the compressor 30 providing air conditioning or heating with a reduced need for power. Therefore, the thermo-volumetric motor converts what would otherwise be waste heat from a refrigeration cycle into an air conditioning application which may require little additional electrical power consumption. Accordingly, the COP effect is used to enhance the thermo-volumetric motor to at least semi self-sustaining status. Other heat sources may be required as illustrated depending on the cooling and/or heating load requirements of the system.

In all embodiments described and illustrated the thermo-volumetric motor 10 is critical insofar as it drives the air conditioning compressor such as 30. In an air conditioning application the system would typically be of a split air conditioning system design being simple and compact and having minimal noise within a building. The electrical motor 36 and compressor 30 are directly coupled to the expeller 20 with a direct mechanical power conversion between these devices with zero electrical power loss. The electrical motor 36 can be used as start-up, back-up or top-up as needed. The belt drive 38 is generally designed as a reducer in order to optimise the performance or match the speed of the compressor 30.

The thermo-volumetric cycle 14 includes a pump 40 designed to recirculate the refrigerant gas around the cycle 14. Another pump 42 may be included between the waste heat source 26 and the heat exchanger 24 as a means of

transferring heat. It should also be appreciated that an electronic control system will typically be incorporated to control the various components described.

The thermo-volumetric motor 210 and vapour-compression refrigeration cycle 212 of Figure 2 is similar to that of Figure 1 except it relies upon ambient cooling rather than forced cooling via the evaporator 232. The ambient cooling is effected using a turbine condenser 211 located downstream of the expeller 220. This is appropriate where a suitable ambient source is available and maximises the cooling load of the refrigeration cycle 212. The system of Figure 2 also excludes the electric motor 36 but rather relies upon the heat source 226 in initiating or sustaining operation of the thermo-volumetric motor 214.

The thermo-volumetric motor 310 and refrigeration cycle 312 of Figure 3 uses a turbine compressor 311 or a boundary layer pump for pumping the refrigerant gas. In this instance the pressurised refrigerant gas does not exchange heat with the refrigerant cycle 312 via the evaporator 332. Once again this maximises the cooling load of the standard air conditioning refrigeration cycle 312. Both the compressor 330 and the turbine compressor 311 or a boundary layer pump are directly coupled to the turbines 318 and 320. It is expected that electrical power will be required to start up the system or use as a top-up with no external heat input.

The system of Figure 4 is substantially identical to the thermo-volumetric motor and refrigeration cycle of Figure 1 with the inclusion of a generator designated as 411. The generator 411 is directly coupled to a common shaft of

the turbines 418 and 420 and can be used for electrical generation or motive power generation in static or mobile applications from small to large sizes such as that required in power houses, vehicles or boats.

Figure 5 illustrates one form of another aspect of the invention. In this embodiment there is a thermo-volumetric motor shown generally as 510 comprising a continuous fluid path formed of a single stream 511 and dual streams 513 and 515. The single stream 511 of the thermo-volumetric motor 510 includes a pair of turbines 518 and 520 constructed and arranged in a similar manner to the preceding embodiments. A mixing chamber 522 is located upstream of the turbines 518 and 520.

A vapour-liquid separator 517 is positioned downstream of the expeller 520 and is designed to provide liquid and vapour fractions for the respective dual streams 513 and 515. The vapour fraction flows to a compressor 530 of a standard vapour-compression refrigeration system. The pressurised vapour from the compressor 530 then exchanges its latent heat with the liquid fraction of the other stream via a condenser 519 through which both of the dual streams 513 and 515 pass. The dual streams 513 and 515 then combine in a heat exchanger 521 located upstream of the mixing chamber 522. As with the preceding examples the heat exchanger 521 is in heat conductive communication with an external heat source 526.

Importantly the compressor 530 is directly coupled to a common shaft of the turbines 518 and 520 for the production of power. It will be appreciated that this application can be used for electrical generation or motive power such as that required in vehicles or boats. In essence, the thermo-volumetric motor and vapour-

compression refrigeration cycle of the preceding examples have been combined into a single cycle. This is made possible through incorporation of the separator 517.

Figure 6 is a schematic of another thermo-volumetric motor 610 and vapour-compression refrigeration cycle 612 similar to that of Figure 1 except that the turbines 18 and 20 are to be replaced with a hydraulic motor 618 such as that disclosed in the applicants International patent application No. PCT/AU95/00655. Further, it relies upon ambient cooling rather than forced cooling via the evaporator 632. The ambient cooling is effected using a condenser 611 located downstream of the hydraulic motor 618. This is appropriate where a suitable ambient source is available and maximises the cooling load of the refrigeration cycle 612. The system of Figure 6 also excludes the electric motor 36 but rather relies upon the heat source 626 in initiating or sustaining operation of the thermo-volumetric motor 614.

Figure 7 is a schematic of yet another thermo-volumetric motor 710 in conjunction with a vapour-compression refrigeration cycle 712 which are substantially identical to the thermo-volumetric motor and refrigeration cycle of Figure 1 with the inclusion of a generator designated as 711. The generator 711 is directly coupled to a common shaft of the hydraulic motor 718 and can be used for electrical generation or motive power such as that in vehicles or boats.

Figure 8 is a schematic of one embodiment of a further aspect of the invention relating to a vapour-absorption refrigeration system and a thermo-volumetric motor combination designated generally as 800. The vapour-

absorption refrigeration system/thermo-volumetric motor 800 comprises a continuous vapour-absorption cycle 801 being adapted to carry a refrigerant/working fluid, in this example ammonia, and water mixture. The continuous vapour-absorption cycle 801 includes a condensor or absorber 803 located upstream of a heat generator 805. The vapour-absorption cycle 801 of this particular example also includes a hydraulic motor positioned between the heat generator 805 and the absorber 803. The hydraulic motor 807 includes one or more hydraulic cylinders such as 809 together with the hydraulic motor 813 which is operatively coupled to an electrical generator 815. The ammonia and water mixture is expanded through one side of the hydraulic cylinder 809 whilst in this embodiment pressurised oil is driven through an opposite side of the hydraulic cylinder 809 so as to actuate the hydraulic motor 813. The heat generator 805 is in heat conductive communication with a driving heat source 817 which in this example is hot water being recirculated at a temperature of between 85 to 90°C. The condensor or absorber 803 is a closed vessel which is in heat conductive communication with an ambient heat sink which is in the form of cooling water at a temperature of between 20 to 25°C.

In operation, the vapour-absorption refrigeration system/thermo-volumetric motor 800 of Figure 8 involves the following general steps:

(i) the ammonia and water mixture is partially evaporated through the heat generator 805;

(ii) an ammonia gas fraction flows to and is expanded within the hydraulic cylinder 809 whereas an unevaporated fraction of the ammonia and water

mixture is diverted to the condenser or absorber 803;

(iii) the expanded ammonia gas is absorbed together with the unevaporated fraction of the ammonia/water mixture in the absorber 803; and

(iv) the ammonia and water solution is recirculated to the heat generator 805 via a recirculatory pump 819.

The vapour-absorption cycle using in this example ammonia gas has a COP effect similar to the vapour-compression cycle of the preceding embodiments. The vapour-compression cycle uses a compressor which requires electric input to compress the vapour whereas the vapour-absorption cycle uses a solution to absorb the vapour which requires heat and not electrical input. The ammonia and water solution has an affinity towards and thus absorbs the expanded ammonia gas entering the condensor 803. Furthermore, in this example the hot water from a diesel engine may serve as the driving heat source 817 to effect vaporisation of the working fluid such as the ammonia and water mixture. The vapour-absorption cycle does not require a compressor, and accordingly represents a different cycle to implement than the vapour-compression cycle. In its implementation, the vapour-absorption cycle, using ammonia, utilises the fact that the temperature of the ammonia exiting the hydraulic motor 807, is generally lower than the ambient temperature of the surrounding atmosphere. As a consequence the ammonia will absorb heat energy from the surrounding atmosphere. The consequence of this aspect of the vapour-absorption cycle is that the energy content of the ammonia is raised by absorption of free energy from the surrounding

atmosphere and therefore requires less heat energy input before its return to the heat generator 805.

Figure 9 is a schematic of a thermo-volumetric motor 900 of an embodiment according to yet another aspect of the invention. This motor is similar in construction to the multiple turbine motor system of the applicants disclosed in Australian provisional patent application No. PQ4237. However, in this instance hydraulic cylinders are operatively coupled to a hydraulic motor and a corresponding generator. The thermo-volumetric motor 900 of this embodiment comprises two power cycles designated generally as 901 and 903 each having a continuous respective stream 905 and 907 being adapted to carry a compressible fluid which in this example is a refrigerant gas. The multiple power cycles 901 and 903 also include a common continuous stream 909 which is adapted to carry an incompressible fluid, such as pressurised oil. Each of the power cycles such as 901 includes a hydraulic cylinder such as 913 being adapted to carry the compressible and the incompressible fluids on its respective opposite sides. Furthermore, each of the power cycles such as 901 includes a heat exchangers 915 operatively coupled to a waste heat source. In this particular construction of the thermo-volumetric motor 900 the waste heat source for one of the power cycles such as 901 is a hot exhaust waste 917 from a diesel engine whereas the water radiator waste 919 of the diesel engine serves as the waste heat source for the other power cycle 903. The hot exhaust of this example is at a temperature of about 500°C and the water radiator at a temperature of around 90°C. Otherwise, each of the continuous streams 905 and 907 of the respective power cycles includes a recirculatory pump such as 921

located downstream of a condensor 923. The heat exchanger on the "hot exhaust" side of the motor 900 is of a fin and tube construction whereas the heat exchanger on the "water radiator" side is of a shell and tube construction. The common continuous stream or common hydraulic oil train 909 provides a flow of oil to a hydraulic motor 923 which is operatively coupled to an electrical generator 925.

In operation, the waste heat source heats the refrigerant gas of the respective power cycle wherein the gas is expanded through one side of the respective hydraulic cylinder such as 913. The expanded refrigerant gas is then condensed within the respective condensor such as 923 and recirculated to the heat exchanger such as 915 via the recirculatory pump 921. Expansion of the refrigerant gas through the hydraulic cylinder drives the pressurised oil on the opposite side of the cylinder so as to effect a flow of the pressurised oil through the hydraulic motor 923. The pressurised oil is then returned to the respective hydraulic cylinder 913 whilst the hydraulic motor 923 actuates the electrical generator 925. Otherwise, the principal of operation of this thermo-volumetric motor is similar to that disclosed in the applicant's Australian provisional patent application No. PQ4237 the disclosure of which is included herein by way of reference.

Now that several embodiments of the various aspects of the invention have been described in some detail it will be apparent to those skilled in the art that these embodiments of the invention have at least the following advantages:

(i) the thermo-volumetric motor and vapour-compression refrigeration cycle when combined have low operational costs compared to existing air conditioning systems;

(ii) the thermo-volumetric motor and vapour-compression refrigeration cycle are environmentally friendly;

(iii) the apparatus and method maximise waste heat energy recovery in generating motive power; and

(iv) the configuration of the apparatus including single or multiple power cycles adapted to recover waste heat enables significant waste heat recovery.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. For example, the turbines of the thermo-volumetric motor may be replaced with one or more hydraulic motors such as that disclosed in the applicants International patent application No. PCT/AU95/00655. Further, it is not essential that the air conditioning refrigeration cycle or system is a standard system although this is preferable.

All such variations and modifications are to be considered within the scope of the present invention the nature of which is to be determined from the foregoing description.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A thermo-volumetric motor comprising a continuous fluid path adapted to carry a working fluid, said path including one or more turbines or a hydraulic motor at least one of which is operatively coupled to a compressor of a vapour-compression refrigeration system, the fluid path adapted to be in heat conductive communication with at least a condenser of the vapour-compression refrigeration system whereby in operation the working fluid recovers latent heat from the condenser to effect expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the vapour-compression refrigeration system, said fluid thereafter condensing and recirculating to recover latent heat from the condenser.

2. A thermo-volumetric motor as defined in claim 1 wherein the continuous fluid path is also adapted, between said turbines or the hydraulic motor and the condenser, to be in heat conductive communication with an evaporator of the vapour-compression refrigeration system whereby in use the latent heat of vaporisation of a refrigerant gas flowing through the evaporator effects cooling of the working fluid.

3. A thermo-volumetric motor as defined in claim 1 wherein the fluid path is not in heat conductive communication with the condenser and the fluid path additionally comprises a working fluid condenser positioned downstream of said turbines or the hydraulic motor.

4. A thermo-volumetric motor as defined in claim 1 wherein the fluid path includes a turbine compressor or a boundary layer pump coupled to and thus driven by the turbines or the hydraulic motor, the turbine compressor or the boundary layer pump located downstream of said turbines or the hydraulic motor.

5. A thermo-volumetric motor as defined in any one of the preceding claims wherein the continuous fluid path further comprises a heat exchanger disposed between the condenser of the vapour-compression refrigeration system and said one or more turbines or the hydraulic motor, the heat exchanger adapted to be in heat conductive communication with an external heat source which thus transfers heat to the working fluid in the continuous fluid path via the heat exchanger.

6. A thermo-volumetric motor as defined in any one of claims 1 to 4 wherein an electrical motor is coupled to the compressor and said turbines or the hydraulic motor is thus driven by an external electrical power supply.

7. A thermo-volumetric motor as defined in any one of the preceding claims wherein the continuous fluid path includes multiple turbines coupled to one another, one of said multiple turbines being operatively coupled via a mechanical drive such as a belt drive to the compressor or an electric motor connected to the compressor.

8. A thermo-volumetric motor as defined in any one of the preceding claims wherein the continuous fluid path also includes one or more mixing chambers located upstream of the multiple turbines, said chambers each being

designed to receive and mix a gas and a liquid component of the working fluid so as to produce a wet gaseous working fluid.

9. A thermo-volumetric motor as defined in claim 8 wherein the multiple turbines are boundary-layer turbines which operate effectively with the wet gaseous working fluid.

10. A thermo-volumetric motor as defined in any one of the preceding claims wherein said one or more turbines or the hydraulic motor are mechanically coupled to a power generator designed for electrical or motive power generation in static or mobile applications.

11. A thermo-volumetric motor as defined in any one of the preceding claims wherein the continuous fluid path further includes a pump being designed to recirculate the working fluid around said path.

12. An air conditioning system and a thermo-volumetric motor combination comprising:

a continuous vapour-compression refrigeration cycle adapted to carry a refrigerant or working fluid, said cycle including at least a compressor located upstream of a condenser which is positioned upstream of an evaporator; and

a continuous fluid path adapted to carry an other working fluid, said path including one or more turbines or a hydraulic motor being coupled to the compressor, the fluid path being in heat conductive communication with at least the condenser whereby in operation the other working fluid recovers latent heat from the condenser to effect

expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the air conditioning system, said other working fluid thereafter condensing and recirculating to recover latent heat from the condenser.

13. A method of generating motive power, said method comprising the steps of:

providing a thermo-volumetric motor including a continuous fluid path adapted to carry a working fluid, said path including one or more turbines or a hydraulic motor;

coupling one of said turbines or the hydraulic motor to a compressor of a vapour-compression refrigeration system; and

coupling the continuous fluid path to the vapour-compression refrigeration system wherein at least a condenser of the vapour-compression refrigeration system is in heat conductive communication with said path whereby in operation the working fluid recovers latent heat from the condenser to effect expansion of said fluid which drives said one or more turbines or the hydraulic motor which drives the compressor and thus the vapour-compression refrigeration system, said fluid thereafter condensing and recirculating to recover latent heat from the condenser.

14. A thermo-volumetric motor comprising a continuous fluid path adapted to carry a working fluid, said path being formed of a single stream and dual streams, the single stream including one or more turbines or a hydraulic motor at least one of which is operatively coupled to a compressor of a vapour-compression

refrigeration system or a boundary layer pump, and a vapour/liquid separator located downstream of said turbines or the hydraulic motor, the separator providing vapour and liquid to each of the respective dual streams, one of the dual streams including the compressor or the boundary layer pump which is designed to pressurise the vapour, the dual streams together being connected to and in heat conductive communication with a condenser such that the latent heat of the pressurised vapour is exchanged with the liquid in the other of the dual streams, said dual streams thereafter combining for mixing of the vapour and liquid which drives said one or more turbines or the hydraulic motor which thus drives the compressor or the boundary layer pump of the vapour-compression refrigeration system.

15. A vapour-absorption refrigeration system and a thermo-volumetric motor combination comprising a continuous vapour-absorption cycle being adapted to carry a refrigerant/working fluid and water mixture, said cycle including a condensor located upstream of a heat generator which is upstream of one or more turbines or a hydraulic motor operatively coupled to a generator whereby in operation the heat generator effects partial vaporisation of the refrigerant/working fluid and water mixture wherein a refrigerant gas fraction is expanded through said turbines or the hydraulic motor which drives the generator, and an unevaporated fraction of said mixture is diverted to the condensor and combined with the expanded refrigerant gas fraction in the condensor and thereafter recirculated to the heat generator.

16. A method of generating motive power, said method comprising the steps of:

providing a continuous vapour-absorption cycle being adapted to carry a refrigerant/working fluid and water mixture, said cycle including a condensor located upstream of a heat generator which is upstream of one or more turbines or a hydraulic motor operatively coupled to a generator;

evaporating at least part of the refrigerant/working fluid mixture in the heat generator;

expanding a refrigerant gas fraction of said mixture through the turbines or the hydraulic motor which thus drives the generator; and

diverting an unevaporated fraction of said mixture from the heat generator to the condensor where it is combined with the expanded refrigerant gas fraction in the condensor and thereafter recirculated to the heat generator.

17. A thermo-volumetric motor comprising:

one or multiple power cycles each having a continuous stream being adapted to carry a compressible fluid and a common continuous stream being adapted to carry an incompressible fluid;

a hydraulic cylinder dedicated to each of the power cycles wherein the compressible fluid and the incompressible fluid flows to opposite sides of the respective cylinder;

a hydraulic motor included in the common continuous stream, said motor being operatively coupled to a generator; and

a heat exchanger dedicated to each of the continuous streams, said heat exchanger being operatively coupled to

a waste heat source whereby in operation the compressible fluid is heated via the waste heat source in the heat exchanger and expanded through the respective hydraulic cylinder which recirculates the incompressible fluid through the common continuous stream and the hydraulic motor which thus drives the generator.

18. A thermo-volumetric motor as defined in claim 17 wherein the multiple power cycles are in heat conductive communication with each other.

19. A method of generating motive power, said method comprising the steps of:

providing a thermo-volumetric motor including one or more power cycles each having a continuous stream being adapted to carry a compressible fluid and a common continuous stream being adapted to carry an incompressible fluid, a hydraulic cylinder dedicated to each of the power cycles and a hydraulic motor included in the common continuous stream;

heating the compressible fluid in each of the continuous streams and expanding said fluid through the respective hydraulic cylinder;

recirculating the incompressible fluid through the common continuous stream via the hydraulic cylinders thereby driving the hydraulic motor and a generator to which it is operatively coupled.

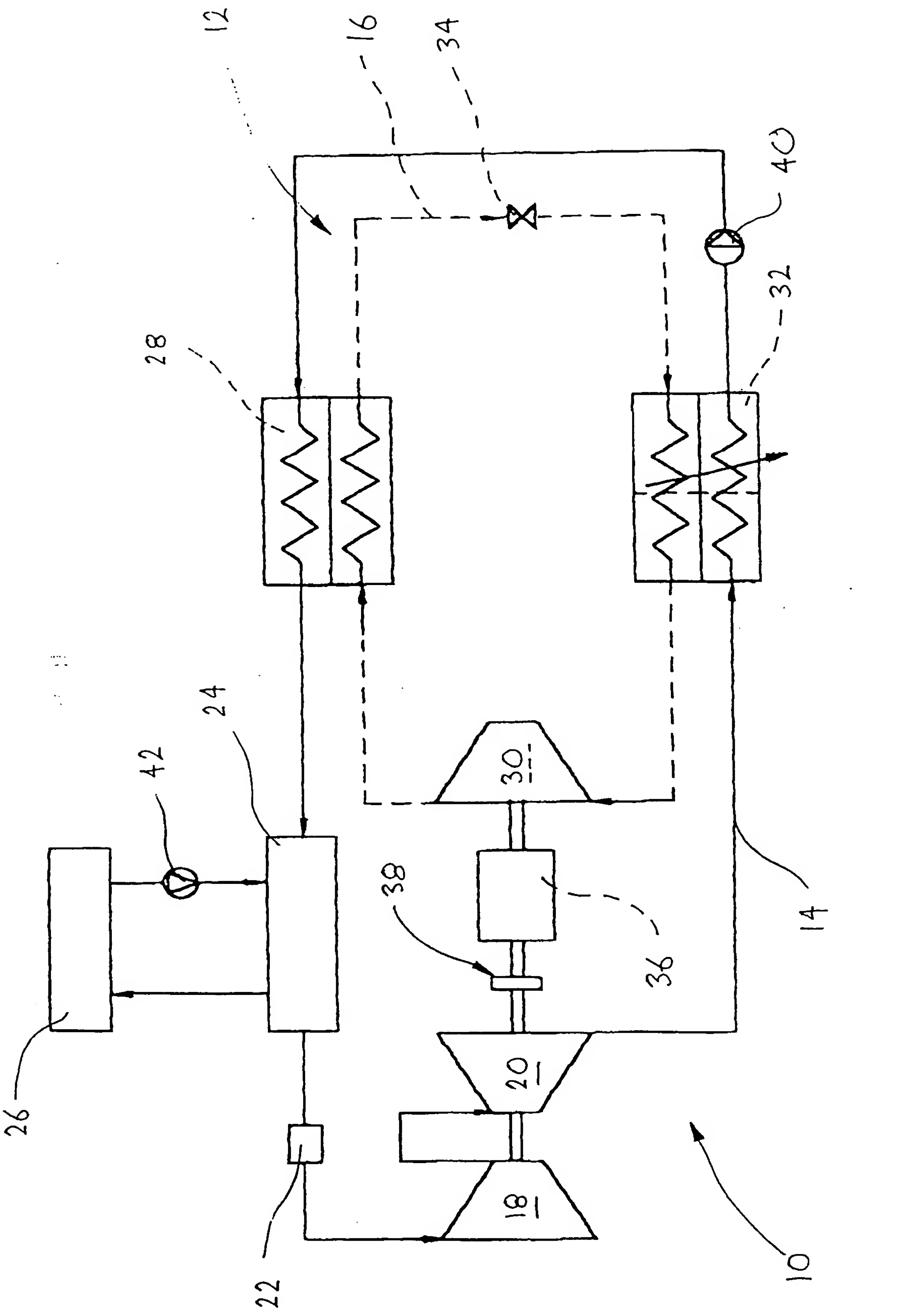

FIG. 1

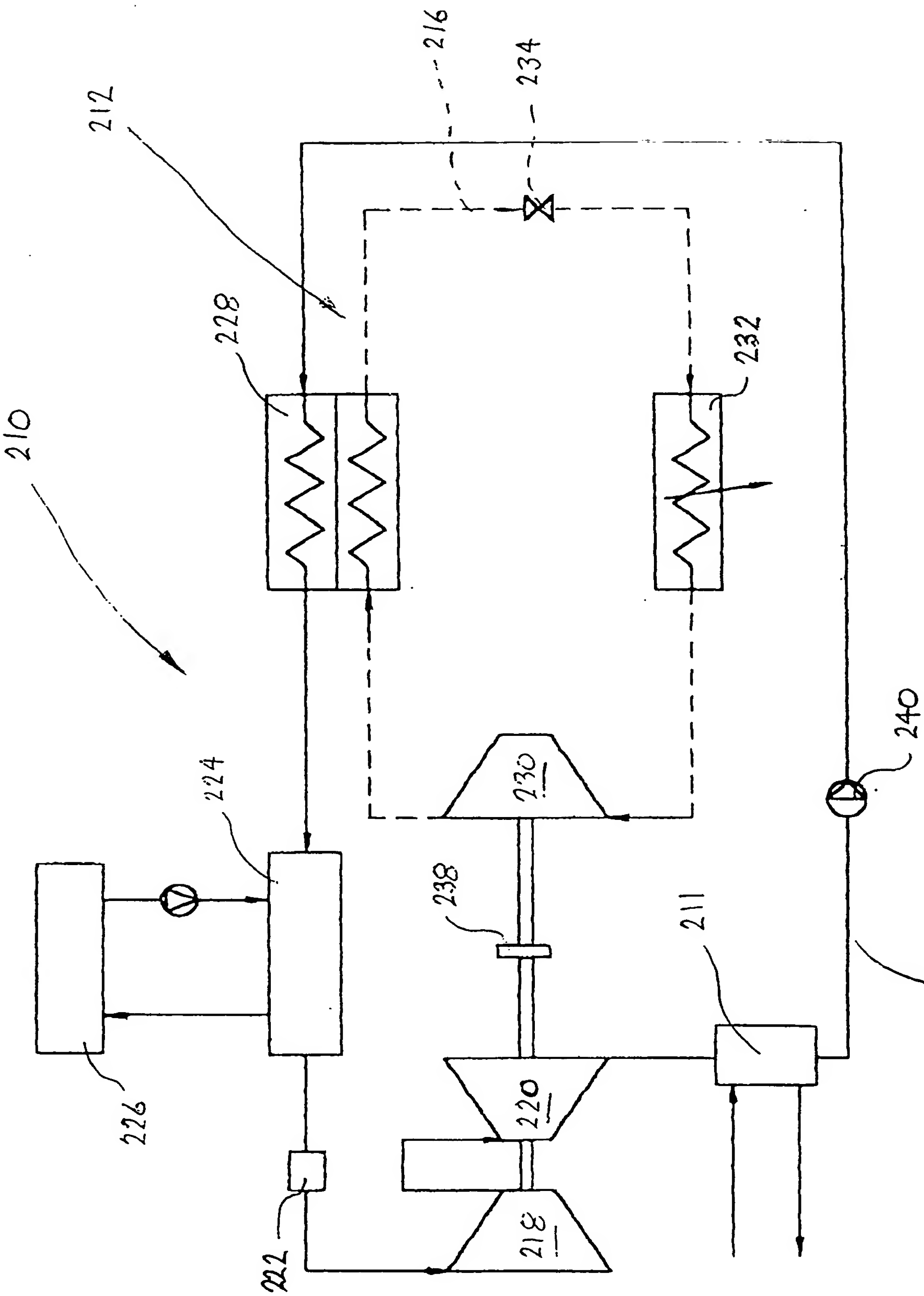

FIG. 2

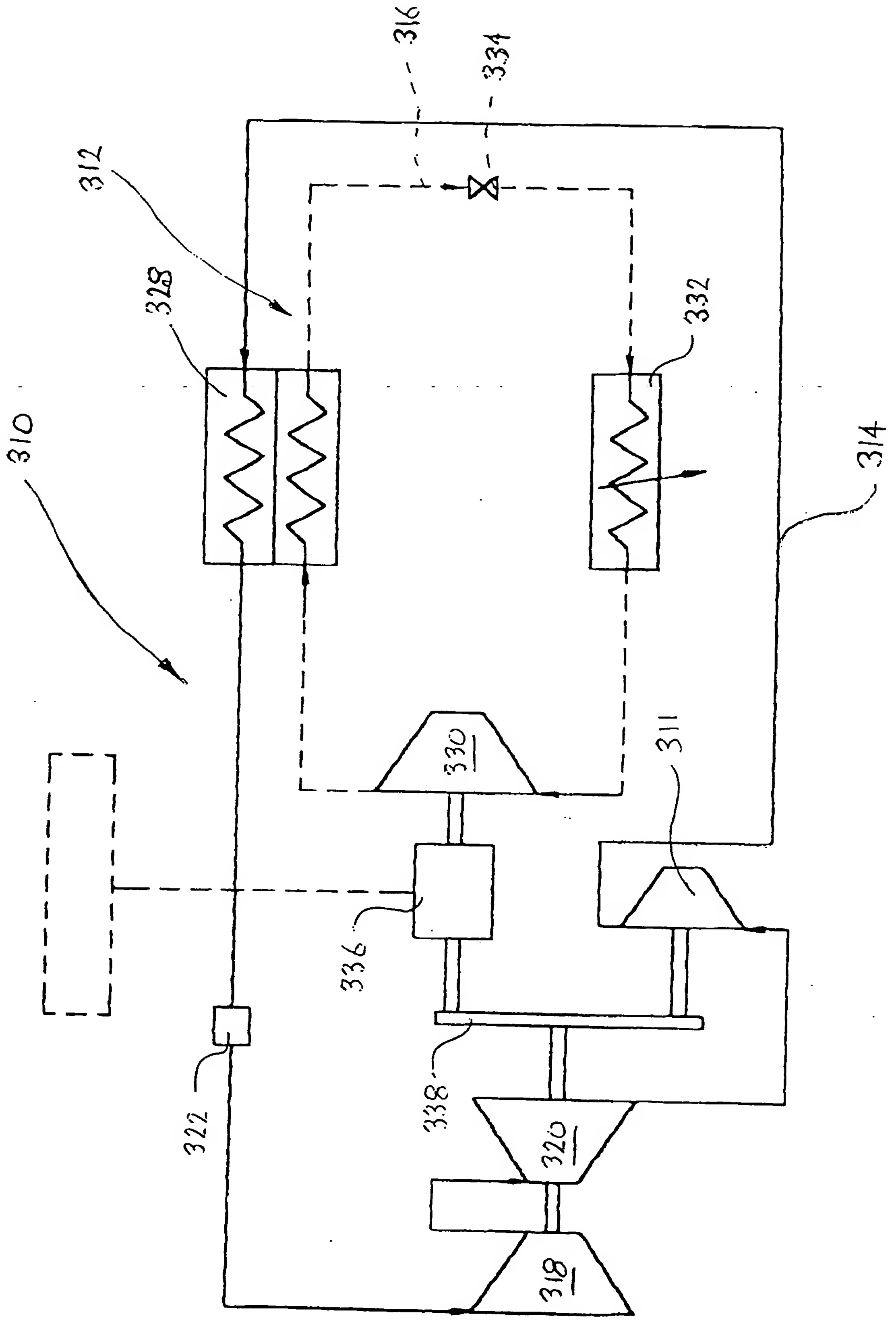

FIG. 3

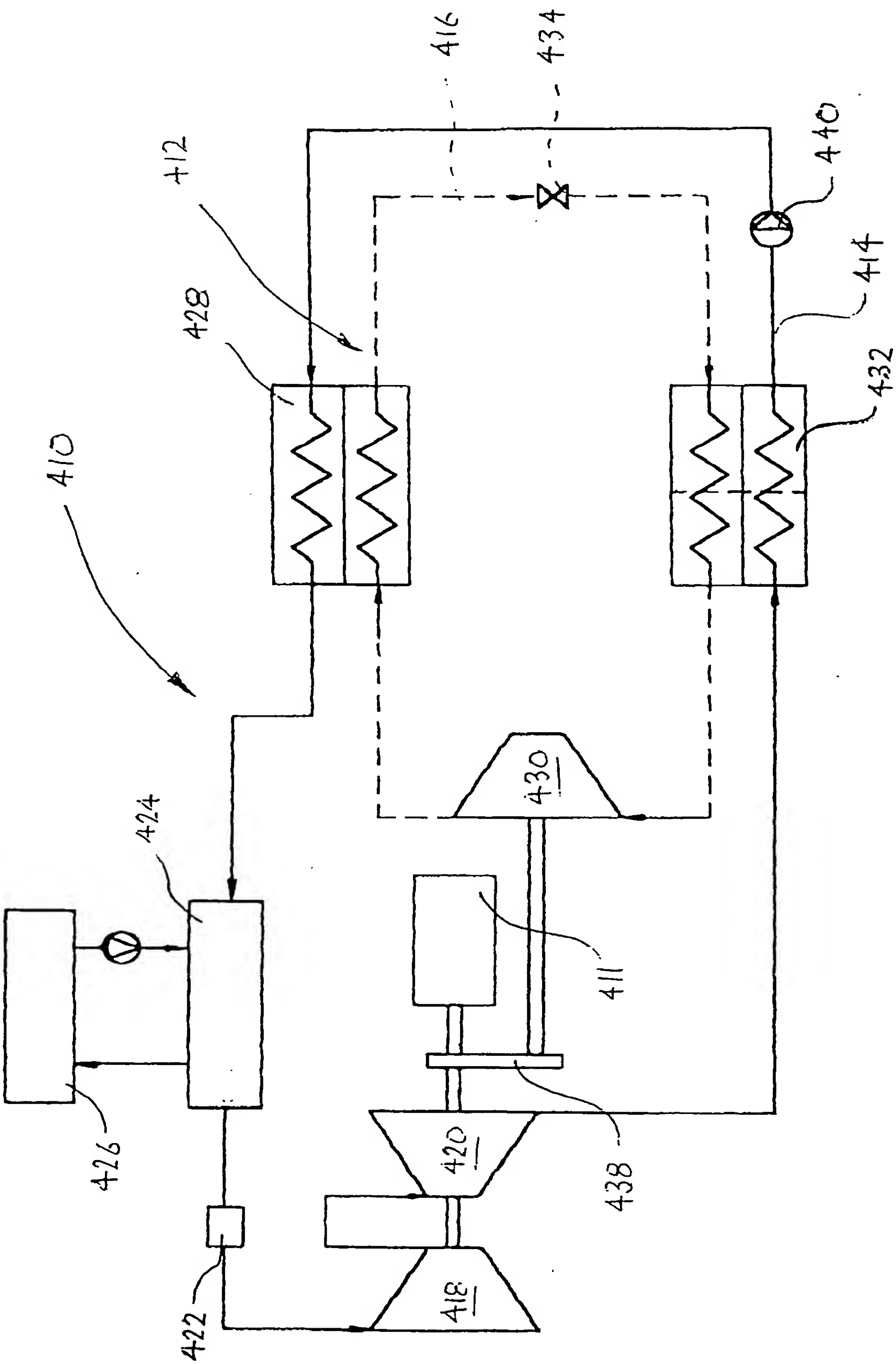

FIG. 4

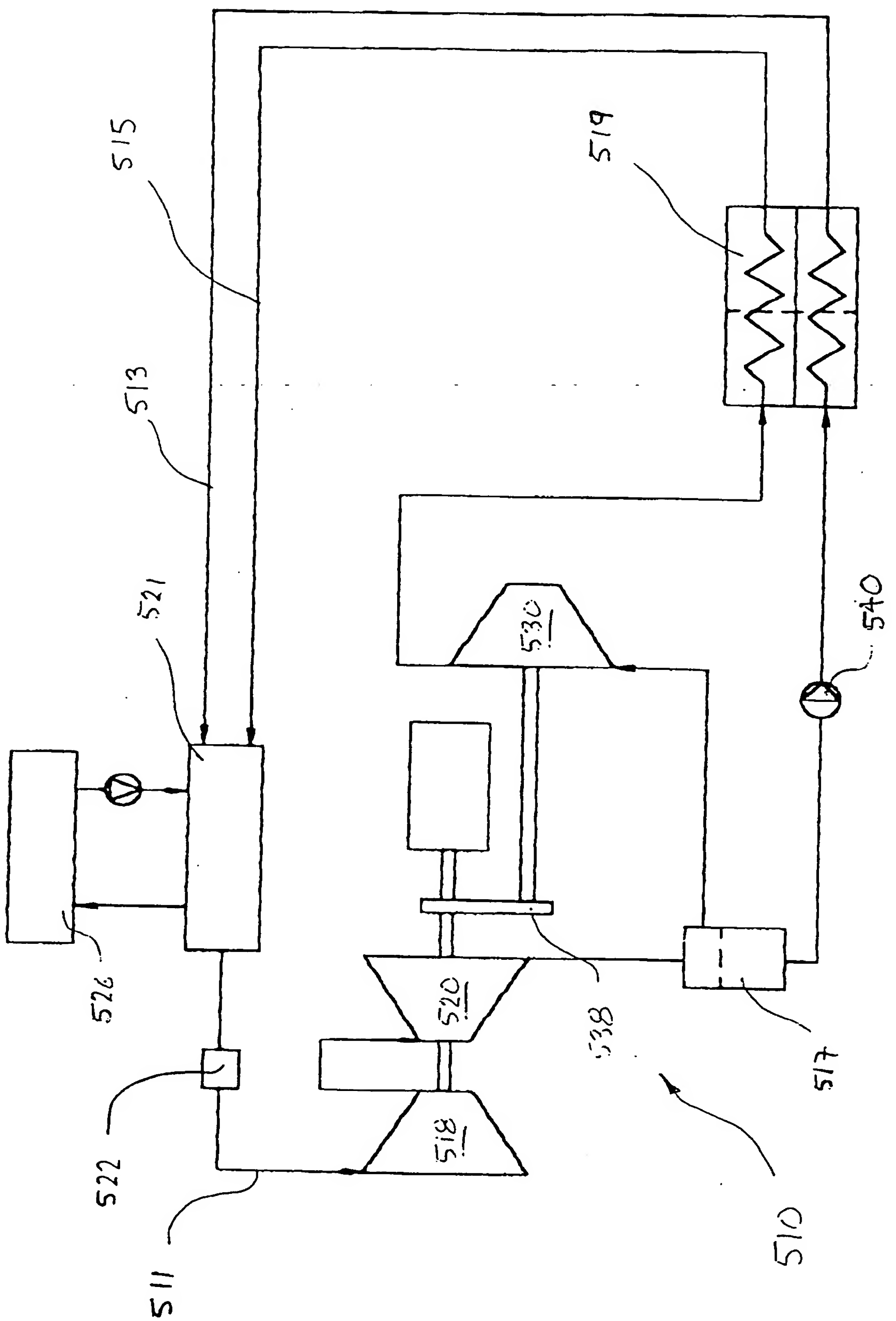

FIG. 5

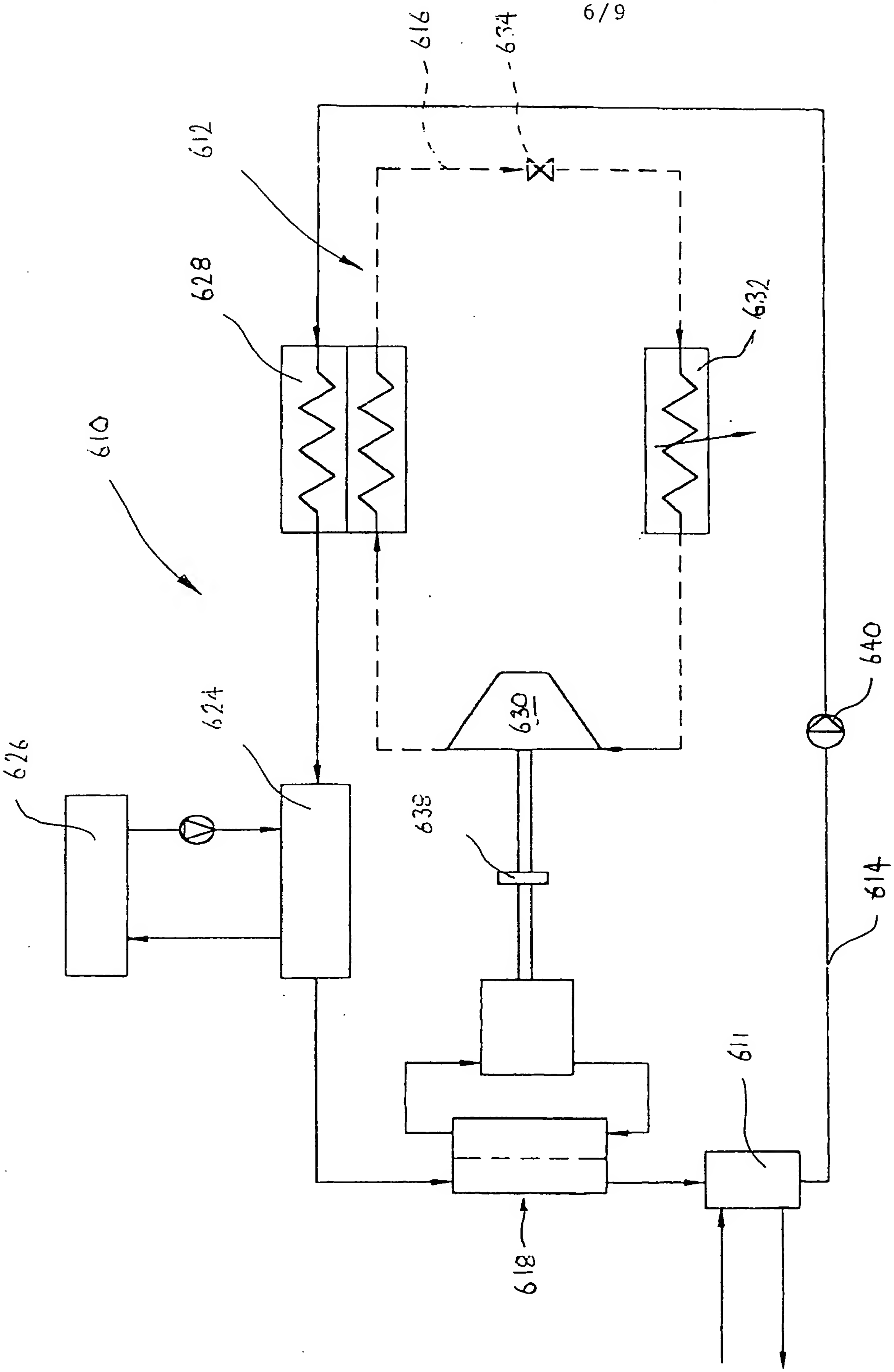

FIG. 6

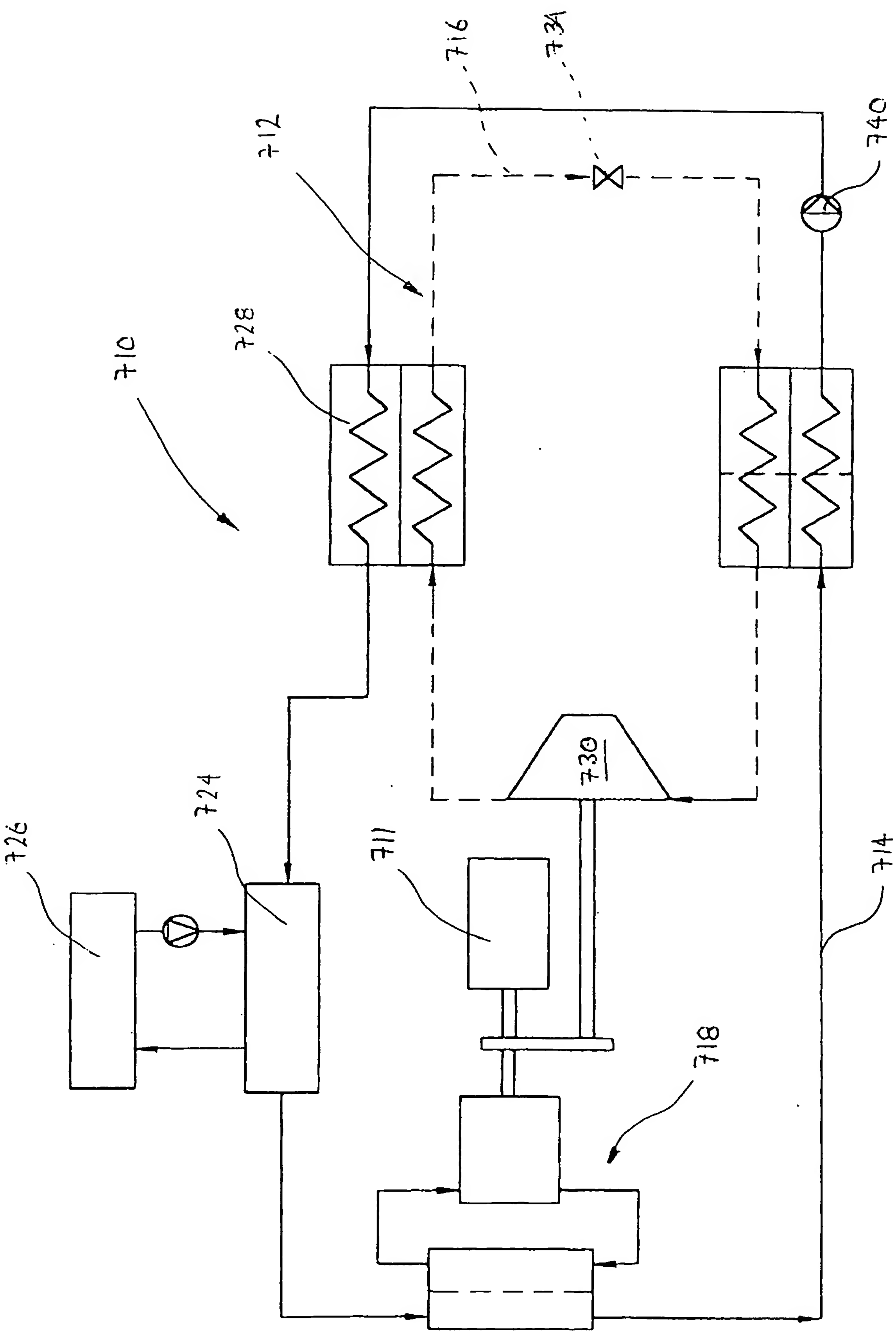

FIG. 7

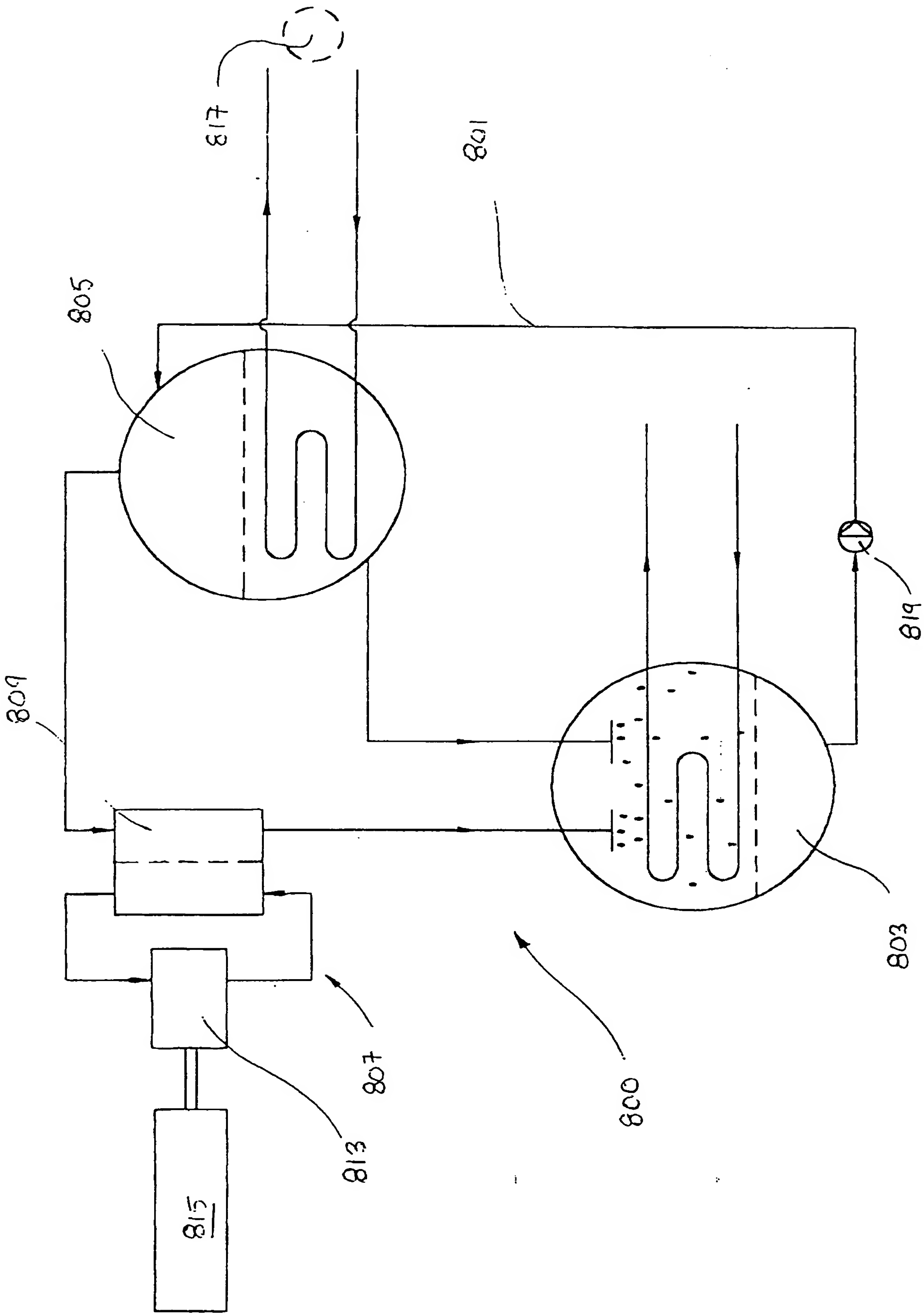

FIG. 8

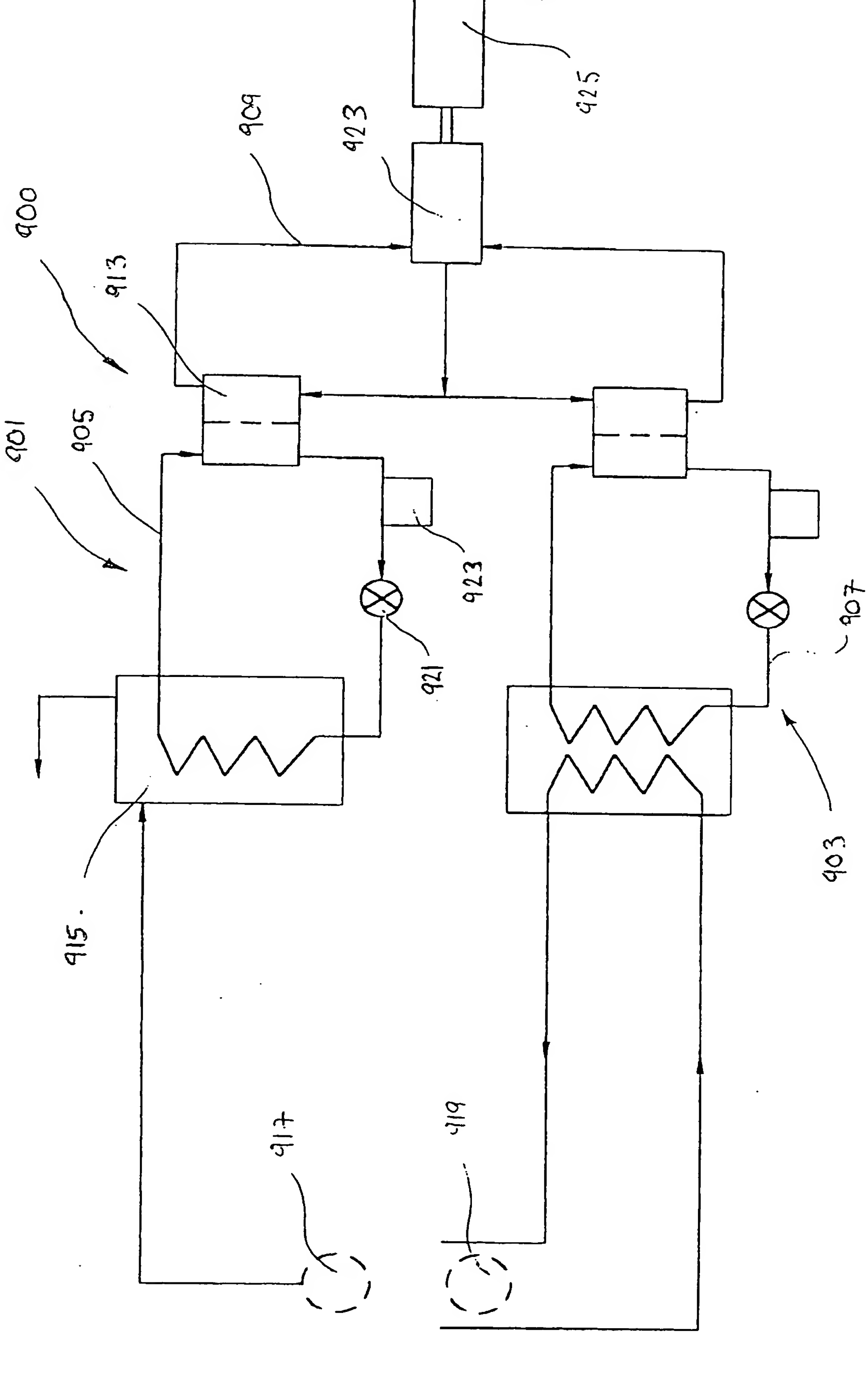

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00469

A.	CLASSIFICATION OF SUBJECT MATTER
Int. Cl. 7:	F25B 27/02, 30/02; F02C 6/18; F01K 25/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : F01K 15/-, 23/-, 25/-, 27/-; F02C 6/18; F25B 27/-, 7/-, 30/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC AS ABOVE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT, USPTO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 85/02881A1 (LIPOVETZ et al.) 4 July 1985 See the whole document	1-13
X	FR 2412692A1 (TEXACO DEVELOPMENT CORPORATION) 20 July 1979 See the whole document	14
X	WO 97/13961A1 (KIM) 17 April 1997 Page 2, line 17-page 26, line 13, Figures 1-4	1-13

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 July 2000	21 JUL 2000
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer ASANKA PERERA Telephone No : (02) 6283 2373

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5875633A (LAWSON Jr.) 2 March 1999 See the whole document	1-13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00469

Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos :

because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos :

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos :

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

(See the supplementary sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-14**

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: II

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are different inventions as follows:

(1) Claims 1-14 are directed to a thermo-volumetric motor, a combination of an air conditioning motor and a thermo-volumetric motor and a method of generating motive power. Claims 1-13 envisage two independent closed circuits for the power generating cycle and the vapour compression cycle while in claim 14 they are combined together to form single/dual stream cycle. It is considered that the combination of a power generating cycle with a vapour compression refrigeration cycle, characterised by part of the expansion work of the former cycle being utilised in the compression stage of the latter cycle and the latent heat of condensation of the latter cycle being utilised in part expansion of the former cycle comprises a first "special technical feature".

(2) Claims 15-16 are directed to a combination of a continuous vapour-absorption refrigeration cycle and a thermo-volumetric motor and a method of generating motive power. It is considered that the extraction of work from a vapour-absorption refrigeration cycle during the expansion of the refrigerant gas fraction thereof characterised by allowing the gas to expand through a turbine/motor arrangement comprises a second "special technical feature".

(3) Claims 17-19 are directed to a thermo-volumetirc motor and a method of generating motive power. It is considered that the combination of a one or more continuous stream power cycles carrying a compressible fluid and a hydraulic cylinder/motor arrangement utilising an incompressible fluid characterised by work extraction from the power cycle(s) by allowing the compressible fluid to expand through respective hydraulic cylinders circulating the incompressible fluid in a common continuous stream comprises a third "special technical feature".

Since the abovementioned groups of claims do not share any of the technical features identified, a "technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept, a priori.

Furthermore, the above groups of claims have distinct classifications under the IPC and therefore it is considered that because of these distinct classifications, constitute separate search areas, these inventions could not be searched without involving significant extra effort.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/00469

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	9713961	AU	73404/96	EP	858552		
FR	2412692	BR	7807924	IT	1101080	JP	54087314
WO	8502881	AU	37803/85	EP	165962		
FR	2476240	DE	3105418	JP	56115896	US	4342201

END OF ANNEX